



National Institute of Standards & Technology

Certificate

Standard Reference Material® 4412L

Molybdenum-99 Radioactivity Standard

Lot Number 39

Ampoule 1

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive molybdenum-99 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. A unit of SRM 4412L consists of approximately 5 mL of a solution, whose composition is specified in Table 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

The certified **molybdenum-99** massic activity value, at a **Reference Time of 1200 EST, 22 April 2014**, is:
 $(25.47 \pm 0.31) \text{ MBq}\cdot\text{g}^{-1}$

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a “measurement result” [2] obtained directly or indirectly from a “primary reference measurement procedure” [3]. The certified value is traceable to the derived SI unit, becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Table 1 and 2. Uncertainties for the certified quantities are expanded ($k = 2$). The uncertainties are calculated according to the ISO and NIST Guide [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

Expiration of Certification: The certification of **SRM 4412L** is valid, within the measurement uncertainty specified, within its half-life-dependent useful lifetime, provided the SRM is handled in accordance with instructions given in this certificate (see “Instructions for Handling and Storage”). The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of Certification: NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser.

Radiological and Chemical Hazard: Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared in the Physical Measurement Laboratory, Radiation Physics Division, Radioactivity Group, M.P. Unterwiesing, Group Leader. The overall production, technical direction and physical measurement leading to certification were provided by R.K. Young and D.B. Golas, Guest Researchers from NRMAP, Incorporated.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Measurement Services Division.

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Table 1. Certified Massic Activity of SRM 4412L, Lot 39, Ampoule 1

Radionuclide	Molybdenum-99
Reference time	1200 EST, 22 April 2014
Massic activity of the solution	25.47 MBq•g⁻¹
Relative expanded uncertainty (<i>k</i> = 2)	1.22 %^(a)

^(a)The uncertainties on certified values are expanded uncertainties, $U = ku_c$. The quantity u_c is the combined standard uncertainty calculated according to the ISO and NIST Guides [4,5]. The combined standard uncertainty is multiplied by a coverage factor of $k = 2$ and was chosen to obtain an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4412L, Lot 39, Ampoule 1

Source description	Liquid in a flame-sealed 5-mL NIST borosilicate ampoule [1]
Solution composition	3.4 mol•L ⁻¹ HNO ₃ with 113 µg Na ₂ MoO ₄ per gram of solution
Solution density	(1.101 ± 0.002) g•mL ⁻¹ at 20.0 °C ^(a)
Solution mass	(5.5306 ± 0.0003) g ^(a)
Photon-emitting impurities	None detected ^(b)
Half-life used	⁹⁹ Mo: (2.7479 ± 0.0006) d ^(c)
Calibration method (and instruments)	Measurements of ionization current ratios relative to radium-226 reference sources using NIST pressurized "4π"γ ionization chamber "A" calibrated using a molybdenum-99 solution whose activity was determined by the 4πβ-γ coincidence efficiency-extrapolation technique.

^(a)The stated uncertainty is two times the standard uncertainty.

^(b)The estimated lower limits of detection for photon-emitting impurities, expressed as massic photon emission rates, as of 23 April 2014 were:

$9.5 \times 10^3 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 30 keV and 55 keV,
 $2.5 \times 10^3 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 60 keV and 120 keV,
 $5.9 \times 10^3 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 125 keV and 155 keV,
 $1.4 \times 10^3 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 160 keV and 620 keV,
 $8.9 \times 10^2 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 630 keV and 720 keV,
 $3.0 \times 10^3 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 730 keV and 790 keV,
 $5.5 \times 10^2 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 800 keV and 890 keV,
 $3.9 \times 10^2 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 900 keV and 980 keV,
 $1.4 \times 10^2 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 990 keV and 1530 keV, and
 $7.7 \times 10^1 \text{ s}^{-1}\cdot\text{g}^{-1}$ for energies between 1540 keV and 2000 keV,

provided that any impurity photons are separated by four keV or more from photons emitted in the decay of molybdenum-99-technetium-99m equilibrium mixture.

^(c)The stated uncertainty is the standard uncertainty. See reference 6.

Table 3. Uncertainty Evaluation for the Massic Activity of SRM 4412L, Lot 39

	Uncertainty component	Assessment Type ^(a)	Relative standard uncertainty contribution on massic activity of molybdenum-99 (%)
1	Ionization-chamber measurement precision for the low-level solution (SRM 4412L, Lot 39); standard deviation of the mean for two sets of measurements on ten ampoules	A	0.01
2	"4 π " γ ionization-chamber calibration factor	B	0.33
3	Radium-226 reference sources ratios	B	0.07
4	Decay correction for radium-226 reference source to correct the calibration factor (for half-life uncertainty of 0.44 %)	B	0.007
5	Correction for sample height positioning during measurements	B	0.50
6	Radium reference source positioning	B	0.05
7	Ionization-chamber charge collection	B	0.05
8	Gravimetric mass measurements	B	0.05
9	Decay correction for molybdenum-99 (for half-life uncertainty of 0.022 %)	B	0.0001
10	Detection limits for photon-emitting impurities	B	0.004
Relative combined standard uncertainty			0.61
Relative expanded uncertainty ($k = 2$)			1.22

^(a)Letter A denotes evaluation by statistical methods; B denotes evaluation by other methods.

INSTRUCTIONS FOR HANDLING AND STORAGE

Handling: If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of both the radioactivity and the strong acid. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure. Refer to the SDS for further information.

Storage: SRM 4412L should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

REFERENCES

- [1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*; available at <http://www.nist.gov/pml/div682/grp04/srm.cfm>.
- [2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sèvres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utls/common/documents/jcgm/JCGM_200_2012.pdf.
- [3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sèvres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utls/common/documents/jcgm/JCGM_200_2012.pdf.
- [4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement*; (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology: BIPM, Sèvres Cedex, France (2008); available at http://www.bipm.org/utls/common/documents/jcgm/JCGM_100_2008_E.pdf.
- [5] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at <http://physics.nist.gov/Pubs/>.
- [6] Laboratoire National Henri Becquerel; *Table of Radionuclides, Recommended Data* (updated 17 January 2012); available at http://www.nucleide.org/DDEP_WG/DDEPdata.htm (accessed May 2014).

Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the internet at <http://www.nist.gov/srm>.